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Burner control method involving the injection of an additional gas and associated combustion system

5 The present invention relates to a method of controlling the operation of a burner for heating the liquid glass feeders coming from a glass furnace.

10 In a continuous glass manufacturing line, the glass is melted in relatively large capacity furnaces that deliver molten glass as output. In certain industries, such as glass furnaces for hollowware, the molten glass must be conveyed right to the glass-forming machines. To transport this molten glass, "feeders" or "forehearth" lined with refractory materials are used.

15 As the glass is being conveyed in this way, it is cooled and also conditioned so that, on leaving the feeders, its temperature is perfectly stable and homogenous to within $\pm 1^{\circ}\text{C}$. To achieve this, the temperature of the glass leaving the feeders must

20 therefore be constant but also perfectly uniform transversely, that is to say over the width of each feeder.

25 It is essential to control the heat transfer method at the surface of the glass over the entire length of the feeder in order to reduce the output temperature gradient. To do this, it is common practice to equip the feeders with a heating device, which heats by combustion of an air/combustible gas mixture above the

30 free surface of the stream of molten glass. This combustion is obtained using air/fuel burners. While the molten glass is flowing, in order for the temperature of the molten glass to be both lowered and homogenized, series of burners are distributed over the

35 entire path of the molten glass. Owing to the number of burners and the difficulty of detecting and controlling the volumes of flue gases that they create, the combustion may be carried out by burners whose oxidizer

is cold air; now, these burners have a generally mediocre efficiency and offer little flexibility as regards obtaining a good transverse thermal profile.

5 To solve these problems, the combustion of an
air/combustible gas mixture has been replaced with
combustion of an oxygen/combustible gas mixture using
oxyfuel burners. This modification has increased the
10 glass production capacity, and also the combustion
efficiency and radiative transfer. Such burners have
been described, for example, in Documents
US-B1-6 431 467 and US 5 500 030. These burners have in
particular the advantage of providing a large operating
15 range, that is to say the possibility of varying the
power - and therefore the fuel and oxidizer flow
rates - much more widely than in the case of air/fuel
burners. Furthermore, the length of the flame of these
burners is constant over their entire operating range.
This property allows them to heat the edge of the
20 feeders, at the point where the glass cools upon
contact with the refractories. They also limit the
thermal gradient, and therefore the difference in
viscosity, between the core of the feeder and the
edges; thus preferential flow of the glass at the
25 center of the feeder is limited. Moreover, the heating
power for a section of feeder by oxyfuel combustion or
with oxygen-enriched air is greater than that which can
be achieved in air/fuel combustion. The wide power
range within which the oxyfuel burners operate allows
30 dynamic regulation which rapidly compensates for the
variations in the process and stabilize the glass
temperature. The feeders may be equipped over their
entire length with several heating zones; in this case,
the oxyfuel burners provide great operating flexibility
35 thanks to greater precision in the temperature
regulation. If the entire length of the feeder is
fitted with oxyfuel burners, this operating flexibility
is even greater. Furthermore, the gas consumption is

reduced. Oxyfuel burners also allow the volume of flue gases to be reduced, which may in certain cases lead to a reduction in the fly-off and volatilization of certain components conveyed in the feeders, such as
5 pigments.

However, this oxyfuel combustion may have certain drawbacks. Firstly, the flame geometry of the feeder burners is particularly important as it is necessary to
10 ensure that the glass stream heating profile is particularly stable and uniform. However, the thermal behavior of the materials that make up the self-cooled oxyfuel burners is generally difficult since the ambient temperature therein is generally high, whereas
15 the gas and oxygen flow rates in each burner are low (low unit power). Thus, to ensure a stable flame profile, there is not as much operating flexibility for these burners as the oxyfuel would allow. In addition, the low-speed flow of the burners may be the source of
20 burner failures requiring maintenance. This is because the burners are cooled by convection with the flow of both the oxidizer and the fuel that they use. In the case of combustion with oxygen, the flow volume is about 70% less than that of combustion with air. The
25 cooling is therefore less effective for the same power. The combustion flame with oxygen is also hotter and more radiating. In addition, at low power, the heating of the burner end-fitting may cause premature cracking and therefore as a consequence rapid fouling and
30 premature wear of the burner. Finally, the feeders must always be at an overpressure, and this pressure is maintained by the volume of the burner flue gases. In aerocombustion, this volume is stabilized - a set of flue gas discharge dampers allows the pressure to be
35 adjusted, which it is necessary to monitor and regulate. In oxycombustion, the volume of flue gases is much lower, and in addition, varies greatly with the power, thereby making it difficult to control the

pressure in the feeders. A pressure-stable method independent of the instantaneous power conditions is therefore sought.

- 5 It is an object of the present invention to propose a method of heating glass feeders using oxyfuel burners that does not have the above drawbacks.

10 It is an object of the present invention to propose a method of heating glass feeders using oxyfuel burners that is flexible and can be easily modified.

For this purpose, the subject of the invention is a method for controlling the operation of a burner for
15 heating the liquid glass feeders coming from a glass furnace, the said burner being fed with a combustible gas and with oxygen, in which an additional gas is injected as a complement to the oxygen so that the sum of the additional gas, oxygen and combustible gas flow
20 rates is greater than or equal to the minimum flow rate D_{MIN} for cooling the burner.

The invention also relates to a combustion system comprising:

- 25 - an oxyfuel burner;
 - a means for feeding the burner with fuel;
 - a means for feeding the burner with oxidizer, cooperating with an oxygen feed means and an additional gas feed means;
30 - a means for measuring the flow rate of at least the oxygen or the fuel; and
 - a means for controlling the additional gas flow rate.

35 Finally, the invention relates to the use of the above system for heating the liquid glass feeders coming from a glass furnace.

Other features and advantages of the invention will become apparent on reading the following description. Embodiments of the invention and methods of implementing it are given by way of non-limiting
5 examples illustrated by Figure 1, which shows the range of power levels obtained with the method and the system of the invention and with the method of the prior art.

The invention therefore firstly relates to a method for
10 controlling the operation of a burner for heating the liquid glass feeders coming from a glass furnace, the said burner being fed with a combustible gas and with oxygen, in which an additional gas is injected as a complement to the oxygen so that the sum of the
15 additional gas, oxygen and combustible gas flow rates is greater than or equal to the minimum flow rate D_{MIN} for cooling the burner.

The invention therefore allows the operation of an
20 oxyfuel burner to be controlled. The term "oxyfuel burner" is understood to mean a burner implementing oxycombustion obtained by mixing a fuel with oxygen. The term "oxygen" is understood to mean an oxygen-containing gas comprising more than 90% by volume of
25 oxygen. The oxygen produced by a VSA (vacuum swing adsorption) process is particularly suitable. According to the essential feature of the invention, an additional gas is injected into the burner as a complement to the oxygen. In general, the additional
30 gas is mixed with oxygen before it is brought into contact with the fuel, for example in a premixing chamber. The amount of additional gas injected as a complement to the oxygen and to the fuel allows the operation of the burner to be controlled according to
35 the following rule: the sum of the additional gas, oxygen and combustible gas flow rates must be greater than the minimum flow rate D_{MIN} for cooling the burner. The value of D_{MIN} may be set for each type of burner

according to the flow rate of the fuel introduced into the burner. More precisely, the value of D_{MIN} may be set in the following manner: D_{MIN} must be sufficient to cool the burner. This flow rate value needed for cooling is
5 specific to the burner used; it can be determined by a person skilled in the art according to the withstand temperature of the said burner. This burner withstand temperature is itself determined beforehand by tests. In practice, the additional gas flow rate may be
10 controlled by a pressure regulator inserted into the line for delivering oxygen to the burner and regulated so as to deliver a stream of oxygen and additional gas at defined pressure. This pressure is set so as to correspond to the minimum gas flow rate needed to cool
15 the burner. Thus, if the oxygen flow rate varies following a variation in fuel flow rate, and so as to maintain a fixed combustible gas/oxygen stoichiometric ratio, the additional gas flow rate also varies in order to compensate or not compensate for the variation
20 in oxygen flow rate in the burner.

According to a first further improved version of the method, it is possible to vary the additional gas flow rate according to the oxygen and combustible gas flow
25 rates by permanently measuring the latter two flow rates and by adjusting the additional gas flow rate so that the sum of the oxygen, additional gas and fuel flow rates is greater than D_{MIN} .

30 According to a second, simplified, particular version of the invention, all that is required is to ensure that the sum of the additional gas and oxygen flow rates is greater than or equal to the minimum flow rate D_{MIN} for cooling the burner. *A fortiori*, the sum of the
35 additional gas, oxygen and combustible gas flow rates is also greater than the minimum flow rate D_{MIN} for cooling the burner. This particular method of implementation is simpler since it is now a question

merely of slaving the additional gas flow rate to the measurement of the oxygen flow rate, for example by means of a simple pressure regulator, without taking into account the value of the combustible gas flow rate.

According to the invention, the additional gas may be an oxidizer gas different from oxygen, or a gas that is inert with respect to fuel. It is preferably at least one of the following gases: air, carbon dioxide, argon, helium, nitrogen or a mixture of these gases. Air is generally best suited owing to its low cost and its composition. An additional gas composed of a quantity of oxygen of around 21% by volume and of at least one other gas different from oxygen is beneficial as, on the one hand, it is favorable to combustion and, on the other, the quantity of oxygen that it introduces may be deducted from the main oxygen injected for burning the fuel.

During a variation in the power of the burner, the fuel and oxygen flow rates increase or decrease proportionally so as to maintain a constant predefined stoichiometric ratio. Depending on the value of the oxygen flow rate used, the additional gas is added as a complement to the oxygen so that the total flow rate of oxygen and additional gas is greater than or equal to D_{MIN} . Consequently, the burner does not suffer any low-power deterioration since, despite the injection of oxygen and fuel at low flow rates, the additional gas provides the gas volume needed to cool the burner. This additional gas also prevents the burner end-fitting becoming fouled by glass deposits and prevents it from being damaged. Furthermore, the additional gas creates a volume of flue gases that allows the operator to obtain and control the overpressure within the feeders. At high power, the additional gas flow rate may optionally be reduced to zero in order to allow

operation only with oxygen. In this case, the sum of the oxygen and the combustible gas flow rates is greater than D_{MIN} .

5 According to a first preferred version of the method, this uses a burner of the type described in US 5 500 030. More particularly, this type of burner comprises:

- a first duct for passage of the oxygen;
- 10 - a second duct, coaxial with the first duct and placed inside the said first duct, for passage of the fuel.

It is preferable for the end of the second duct to be
15 placed set back from the end of the first duct. More preferably, burners of this type are used in which the ratio of the inside diameter of the first duct to the inside diameter of the second duct is between 2/1 and 8/1.

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According to a second preferred version of the method, this uses a burner of the type described in US-B1-6 431 467. More particularly, this type of burner comprises:

- 25 - a first duct for passage of the oxygen;
- a second duct, coaxial with the first duct and placed inside the said first duct, for passage of the fuel;
- an end-fitting placed at the end of the first
30 duct;
- a nozzle placed at the end of the second duct;
- a means for making the fuel swirl, placed on the nozzle at the end of the second duct. According to this second version, the means for making the fuel
35 swirl comprises an object of elongate shape centered aerodynamically inside the nozzle of the second duct, the inside diameter of the said nozzle being greater than the diameter of the object of elongate shape of

the means for making the fuel swirl. The object of elongate shape of the means for making the fuel swirl may consist of at least one helical rod over a portion of its length. This burner may also include a means for
5 making the oxidizer swirl, placed on the end-fitting at the end of the first duct; this means for making the oxidizer swirl may consist of a helical spring. This type of burner is particularly suitable for implementing the method of the invention because it
10 produces a flame of constant length independently of the power variations.

The invention also relates to a system comprising:

- an oxyfuel burner;
- 15 - a means for feeding the burner with fuel;
- a means for feeding the burner with oxidizer, cooperating with an oxygen feed means and an additional gas feed means;
- a means for measuring the flow rate of at least
20 the oxygen or the fuel; and
- a means for controlling the additional gas flow rate.

This combustion system allows the variations in power
25 of the burner to be finely controlled without the drawbacks encountered in this type of burner. Such a system allows the method of controlling the operation of the oxyfuel burner, as described above, to be implemented. In general, the means of controlling the
30 additional gas flow rate is slaved to the means of measuring the flow rate of at least the oxygen or the fuel. This means of controlling the additional gas flow rate may be a pressure regulator or a servovalve, that is to say a valve slaved to a control value. When the
35 means of controlling the additional gas flow rate is a pressure regulator, all that is required is to regulate it so as to deliver the additional gas until the pressure generated by this additional gas and the

oxygen that is delivered is greater than the pressure needed to obtain the minimum oxidizer flow rate D_{MIN} . When the means of controlling the additional gas flow rate is a servovalve, it is possible to slave the opening of the additional gas feed means to one of the following control values: the oxygen flow rate or the fuel flow rate, taking into account the fixed oxygen/fuel stoichiometric ratio. According to one particular method of implementation, in which the additional gas is air, the servovalve may take into account the supply of oxygen from the air in calculating the oxygen/fuel stoichiometric ratio; this method of implementation makes it possible to economize on consumption of oxygen.

Finally, the invention relates to the use of the above system for heating the liquid glass feeder channels coming from a glass furnace.

The graph shown in Figure 1 illustrates the power ranges obtained with the method and the system of the invention and with the method of the prior art. In the case of the system of the invention (solid curve) and the oxyfuel burner of the prior art (dotted curves of the and - - - - - type), the curves give the power (in kW) that it is possible to transfer as a function of the developed power (in kW). The developed power is the power created by the stoichiometric combustion using an oxidizer comprising only oxygen. The transferred power is the power that is actually transferred to the glass. In the case of oxycombustion using an oxidizer comprising only oxygen (oxyfuel burner of the prior art), it may be seen that the transferred power corresponds to the developed power. For combustion using an oxidizer comprising oxygen and the additional gas, although the same power is developed as with the burner of the prior art, it may be seen that the power transferred by the burner

implementing the invention may be lower, on account of the power losses due to the volumes of flue gases in a certain power range. It has been observed that the burner of the prior art is limited to operation, in terms of transferred power and developed power, within the 7 to 10 kW range since below 7 kW the burner cannot operate without suffering deterioration by the absence of a sufficient gas stream (deterioration in the range defined by the dotted curve of the type). Thanks to the system of the invention, this same burner may have its operating range broadened to 0.15 to 10 kW. It may also be emphasized that the method and the device of the invention make it possible to broaden the operating range of the burners of the prior art within a power range that was not accessible in the prior art, even by making them operate in the power range causing them to deteriorate, and that corresponds to the dotted curve of the type in figure 1; it may be seen that this "deteriorating" power range cannot drop below 1 kW of transferred power, whereas the method of the invention allows access to transferred power levels between 0.15 and 1 kW.

By implementing the method and the system of the invention, it is possible to heat the molten glass feeders coming from a glass furnace while maintaining the advantages of oxyfuel burners - namely a broader operating range than for air/gas burners, again for high power levels, optionally controlled flame length and reduction in fuel consumption - while improving the low-power heating profile without the burner deteriorating.

The invention also has the advantage that a stable pressure can be maintained in the feeders because of a flue gas volume that is higher than during low-power all-oxygen combustion.

Owing to the possibility of working with low-power burners, the invention also makes it possible to work with a larger number of burners operating at lower power levels - the heating may thus be more uniform and
5 the quality of the transfer to the glass is improved.

In addition, although the complementary injection of additional gas into the oxygen degrades the combustion efficiency, it does allow, however, the power
10 transferred to the glass to be very finely regulated.

The combustion efficiency is a minimum when the burners operate at low power. However, at these levels the fuel saving is potentially lower. This method has little
15 impact on the economics.

Another advantage of the invention is that it allows the power of the burner to be rapidly adjusted according to the nature of the glass flowing through
20 the feeders. This advantage is more particularly important at the present time because of the continual modifications made to glasses produced in order to follow the fashion trends (colors, etc.).